# Noninvasive Geophysical Monitoring of Clay-Mineral Transformations During Simulated Iron Reduction

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## RESEARCH OBJECTIVES

The importance of iron-bearing clay-sized minerals as a source of bioavailable iron is well documented. During biostimulation, reduction of such accessible ferric compounds by iron-reducing microorganisms can occur rapidly and result in the sequestration of soluble contaminants, such as uranium and chromium in insoluble phases. As the clay-sized fraction is exhausted and more recalcitrant forms of ferric iron are accessed, competition by other microbial strains can result in decreased remediation efficacy. Improved diagnostic methods are needed to elucidate the extent of microbe-induced mineral transformations over the large spatial scales encountered during field experiments.

## APPROACH

The complex-resistivity method was used to monitor the effect of iron-reduction at both lab- and field-scales. The lab experiments investigated the effect of both chemical and enzymatic reduction of iron-bearing clays and clay-sized minerals on complex-resistivity signals. The field experiment used an analogous methodology to track the extent of iron reduction that occurred following acetate amendment of a shallow alluvial aquifer near Rifle, Colorado, designed to stimulate microorganisms capable of co-metabolic U(VI)-reduction.

## ACCOMPLISHMENTS

Alterations in the physiochemical properties of iron-bearing clays and clay-sized minerals, resulting from both abiotic reduction and microbial respiration, led to decreases in the measured values of complex resistivity at the lab scale (Figure 1b). Reduction of structural iron led to an increase in the layer charge of the clay minerals, which resulted in structural collapse and a decrease in the specific surface area. This decrease in surface area was inferred to be the primary cause of the time-varying complex-resistivity signatures. Similar decreases in the phase response of the complex-resistivity signals were observed during the field biostimulation experiment (Figure 1a). The phase decreases corresponded in both space and time to the onset of microbial iron-reduction and reached a maximum following the cessation of active bioreduction. Mineralogical alterations in the clay-sized fraction of the aquifer sediments were believed to be responsible for the observed geophysical anomalies.

## SIGNIFICANCE OF FINDINGS

Noninvasive geophysical monitoring methods have shown sensitivity to the mineralogical changes associated with iron reduction and show promise for monitoring the progress of stimulated subsurface bioremediation at field-relevant scales. Time-varying complex-resistivity anomalies correlated with the exhaustion of bioavailable iron, suggesting an approach for monitoring the sustainability of prolonged iron reduction under stimulated conditions.

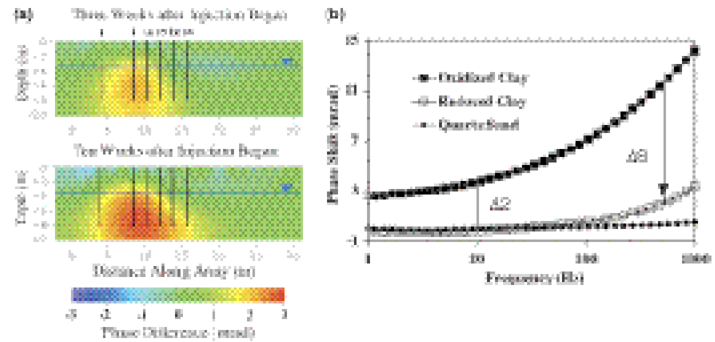

Figure 1. Variations in the complex-resistivity signatures of bioreduced clay minerals resulting from stimulated microbial activity: (a) changes in the phase response measured at the Old Rifle, Colorado, site three and ten weeks after acetate amendment—acetate injection occurred throughout the saturated zone along the location labeled 'I'; and (b) laboratory-derived phase response of oxidized and reduced versions of the same clay mineral as compared to fine quartz sand. The magnitude of the change corresponds to that observed during the field experiments.

## RELATED WEBSITE

http://esd.lbl.gov/ERT/sshubbard

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